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Engineering Note

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Project: CFT Mixer Box
Doc. No: A990422A

Subject: Interpreting Fiber Mapping Spreadsheets

Introduction

This last week I posted to the server[1] a spreadsheet named FULL_CRYO_MAP.XLS which purports to describe the entire map of fibers in one 'supersector' (one fifth of the whole CFT Axial, or 16 contiguous sectors), from the Warm End of the cassette, through the Ananlog Boards (AFE), out the links, through the mixer box and onto the links to the Digital Boards (DFE). The purpose of this spreadsheet was to address the following issues:

- What would the L3 readout look like now that fibers are no longer sorted by sector but are grouped by layer in the cassettes?
- How many bits would have to pass between Mixer Boards in a four-board Mixer to get all the bits from the AFEs into the appropriate DFEs?
- Would simply passing bits from one Mixer Board to the adjacent Mixer Board be sufficient?
- Was it reasonable to assume that all Mixer Boards could be layout-identical, varying only in firmware?
- How many clock ticks worth of data would the Mixer have to buffer before it could start sending data to the DFEs?
- What is the required layout in the AFE from MCM to CPLD to get the right bits on the right links?

To that end, the spreadsheet does some calculating, based upon a system architecture that has a few embedded assumptions. This note will first describe the architecture of the assumed system, and then walk the reader through the various sheets in the spreadsheet.

System Architecture

The CFT system, for purposes of this spreadsheet, consists of 10 identical 'supersectors' of information. Five of these sectors are CFT Axial data, and the other five are CFT Stereo. I ignore the CPS Axial, CPS Stereo and FPS data, noting only that the CPS Axial information will have to pass through the various Mixer Boards. However, all CPS data runs straight through the various Mixer Boards and out to the DFEs; as such, it's a detail of Mixer design that doesn't impact the view from the spreadsheet.

Each 'supersector' contains all the fibers from 16 adjacent sectors in the detector; the fibers land in 7½ cassettes, as shown in Figure 1. To fully utilize the cassettes, the 'halves' are set together, so that the occassional cassette belongs to two different 'supersectors'. Whether the two 'supersectors' are Axial or Stereo really doesn't matter, although one might guess that the fiber plant would tend to alternate them to keep fiber lengths relatively consistent.

[1] at http://d0server1.fnal.gov/projects/triggerelectronics/webdocs/mixerbox/default.html

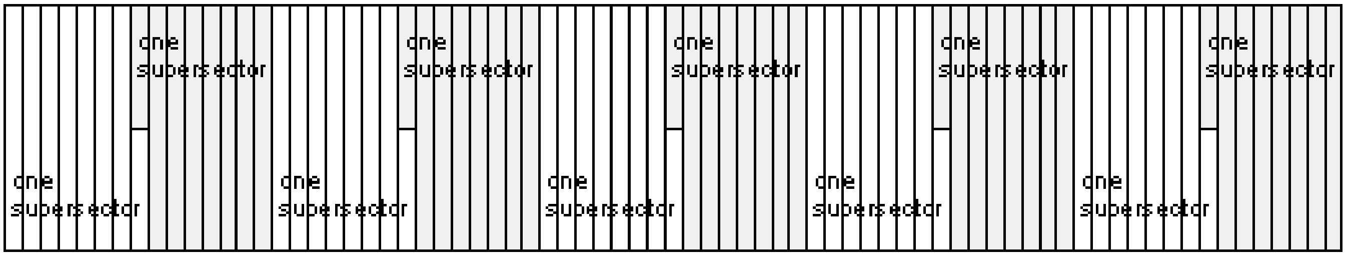

Figure 1

Each rectangle above represents a single cassette; each cassette holds two AFE boards. Within a given 'supersector' there are 14 fully populated boards, times four links per board, plus two half-populated boards, for a total of 60 LVDS links from a 'supersector' to a set of four Mixer Boards. Each set of four Mixer Boards connects at the back side to eight Digital Boards, where each Digital Board services a set of two adjacent sectors. It takes three LVDS links to drive all the data from one sector into a given Digital Board; in addition, each Digital Board has to receive one link's worth of data from the set sent to each neighboring Digital Board, to make a detector without cracks. Since a single Digital Board services two sectors, each Digital Board then receives (3 * 2) + 2 = 8 links worth of data total. Because the Digital Board is also being designed for use in the Broadcaster system, the Digital Board actually has 10 input connections, but we only use eight of them here.

Jamieson Olsen has utilized a color-coding scheme for the links that drive into the Digital Board, described in his Engineering Note #990105A, found at http://d0server1.fnal.gov/users/jamieson/www/notes/990105a.pdf . To summarize, the 'left' half of a Digital Board receives a Red, a Blue and a Yellow link, plus a Green link from the neighboring set of sectors; the 'right' half of a Digital Board receives a Purple, an Orange and a Green link, plus a Red link from the neighboring set of sectors. His graphic is shamelessy copied here as Figure 2.

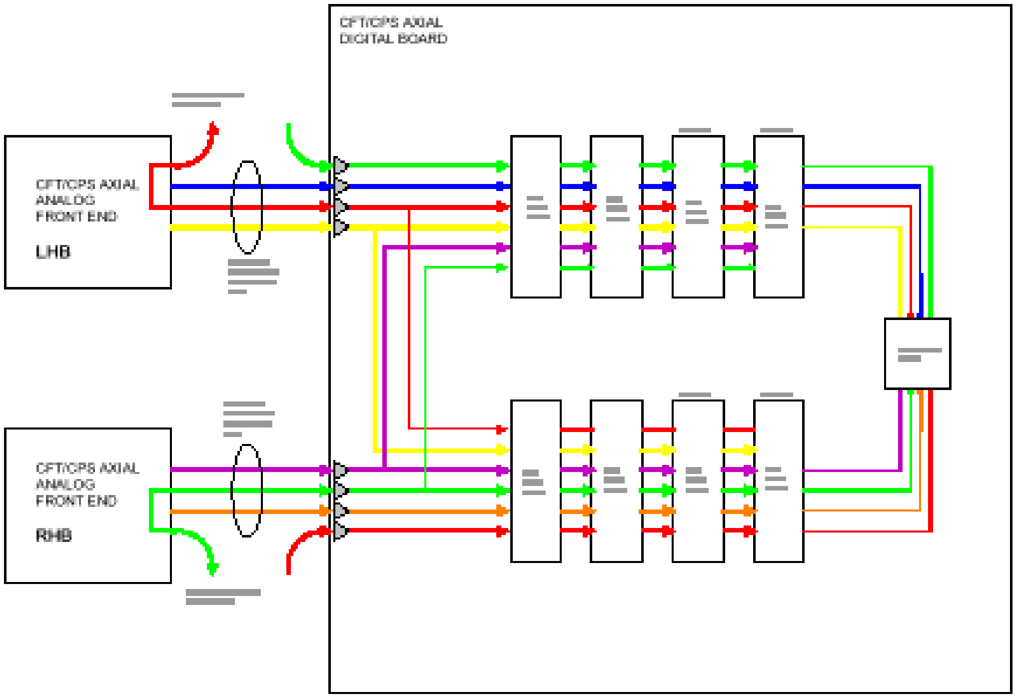

Figure 2

With the introduction of the Mixer system, however, the data is no longer generated directly from the Analog Front End boards, but instead comes from the Mixer. Figure 3 shows the entire setup.

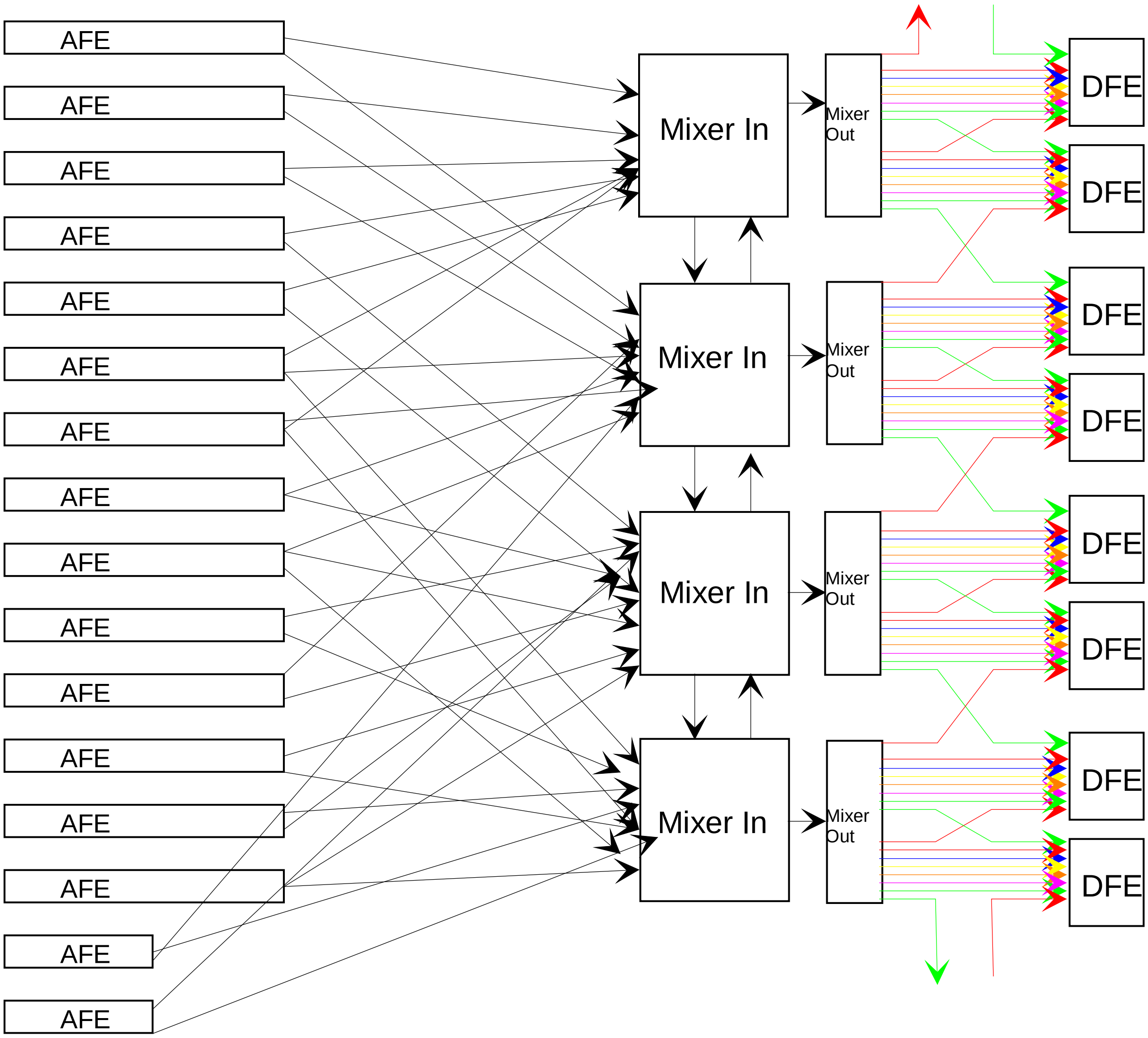

Figure 3

The arrows from the AFE's to the Mixer are not necessarily accurate. The AFE's do route to various Mixer In boards, but leave the exact details to the spreadsheet, not to this cartoon.

Spreadsheet Method

The first thing which must be done to understand this system is to input the data as it appears at the cassettes. The first page of the spreadsheet, named Input Fibers, does just that, as shown in this screen capture:

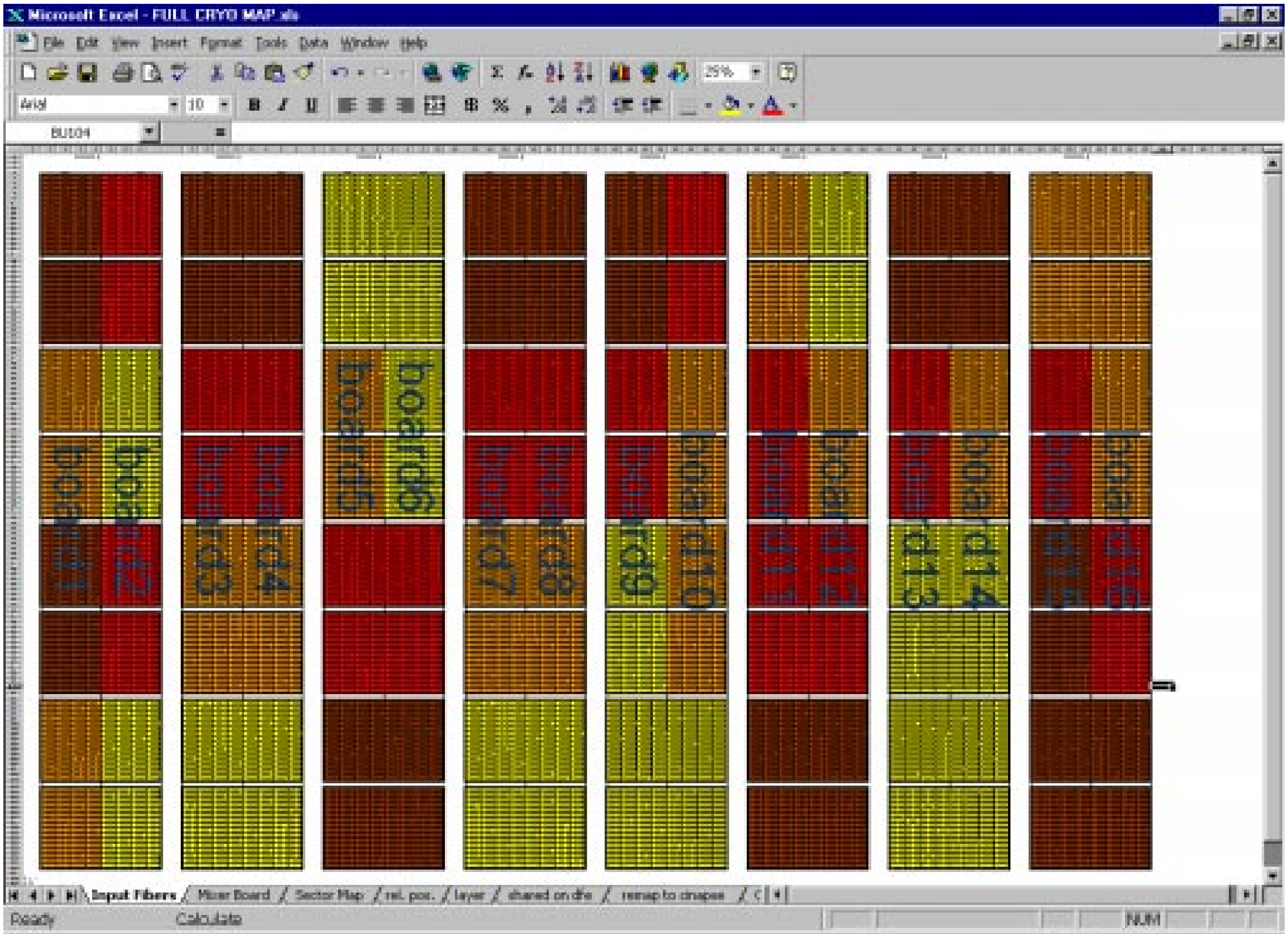

Figure 4

This is a top view of the eight cassettes in a 'supersector'. Each cell of the spreadsheet represents one input fiber. Zoom in far enough, and you'll find names like 'A56' or 'H1103'. These indicate the actual position of the fiber – layer 'A' through layer 'H', and a numerical index in phi angle. The fibers are numbered so that every fiber in the 'supersector' has a unique name. The big 'board x' names are just group names for reader convenience and have nothing to do with the calculations. The fibers are blocked into eight blocks per cassette – to match the Warm End connectors. The color of the cell indicates which Mixer Board the fiber is destined to go to, as per Fred Borcherding's arrangement issued earlier this month. Brown indicates Mixer Board #1, red #2, orange #3 and yellow #4. The four blocks at the lower left are the fibers from the adjacent 'supersector' and have names like Znn to indicate that. In a real system, they'd be more 'A' fibers.

Implicit in this arrangement is how the LVDS links run from the AFEs to the Mixers. Each adjacent pair of blocks on each board drives a single LVDS link. That is, if you number the eight blocks seen by a board as #1 through #8, #1 and #2 will be combined on one link, #3 and #4 on the next link, #5 and #6 on the third link and #7 and #8 on the fourth link.

Mixer Board Page

The Mixer Board page presents the identical information to the Input Fibers page, except that all the cells are filled not with the fiber number, but with a number to indicate the color fill. This is just for convenience later. However, if one changes the colors on the Input Fibers page, the data values in the Mixer Board page must be changed to match.

Sector Map Page

The Sector Map page uses a formula to derive, for every fiber, which of the sixteen sectors within the 'supersector' it belongs to. The generic formula is:

ROUNDUP(VALUE(MID('Input Fibers'!B5,2,9))/(((CODE('Input Fibers'!B5)-CODE("A"))*8)+32),0) which just takes the first letter of the fiber name, finds out how many characters away from ‘A’ it is, and uses that to calculate the number of fibers per sector of the layer; this is then used to figure out which sector the fiber belongs to. On this page, those fibers in the lower left hand groups have to be treated specially because we named them ‘Z’ fibers, so the formula for those is just a little different:

ROUNDUP(VALUE(MID('Input Fibers'!B73,2,9))/(((CODE('Input Fibers'!B73)-CODE("Z"))*8)+32),0)

Rel. Pos. Page

After figuring out what sector each fiber belongs to, the next page then determines the relative position within the sector for each fiber. This is used later to figure out the sharing information between Digital Boards. A somewhat more convoluted formula is used for this, mostly to insure that the right values at exact sector boundaries are calculated. Basically, you just take the fiber number, divide by the sector number it’s in, and use the remainder.

IF(MOD(VALUE(MID('Input Fibers'!B5,2,9)),(((CODE('Input Fibers'!B5)-CODE("A"))*8)+32))=0,((CODE('Input Fibers'!B5)-CODE("A"))*8)+32,MOD(VALUE(MID('Input Fibers'!B5,2,9)),(((CODE('Input Fibers'!B5)-CODE("A"))*8)+32)))

The useful thing to note here is that the cells are all lined up between the pages, so these all have the cells organized in ‘cassette top view’ everywhere. That makes it easy to use copy and paste to generate all the formulas.

Layer Page

Here I just convert the layer letter into a number code, to simplify formulas later. I probably should go back and use this info in the Sector Map and Rel. Pos. pages to make those formulas simpler, but haven’t gotten around to that detail.

Shared on DFE

In the Digital Boards, the fibers on the Red and Green colored links are ‘shared’ with the neighboring Digital Board to provide seamless information. The Mixer has to know which fibers are constrained that they *must* be placed on the Red or Green links, and this page performs that calculation. Two small lookup tables at the top left of the page show, by layer, how many fibers in from each edge things are ‘shared’. These are used to ‘tag’ the fibers.

A reasonable upgrade to this page would be to make a multi-value tag where instead of just having ‘1’ meaning ‘share’ and ‘0’ meaning ‘no share’, use numerical values from 1 to 6 to indicate the actual color link to which the fiber must go. This would provide better design data for the Mixer.

Remap to Cinapse

Cinapse Pin

Remap to MCM

Mcm pin

These four pages copy data previously disseminated that shows how a given Warm End connector position maps to a particular Cin:Apse pin on the AFE, and from there, which Cin:Apse pin gets connected to which MCM input pin. In short, these map the trace routes in the cassette and the AFE and should not be changed.

Clock Tick 1 through Clock Tick 7

Each of these seven pages details how the bits present in the AFE are routed out to the LVDS links. Various analyses are performed, so please reference Figure 5 as this discussion progresses. The page consists of three nearly identical colored areas. Each of the three large colored areas represents one ‘view’ of the data presented across all the boards in the ‘supersector’ during this clock tick. Within each area, the columns have a set order. Column A is notes. Column B is a list of cell addresses – referenced to the original Input Fibers Page – that points to the cell in the left-hand board of the leftmost cassette. Column C is pointers to the cells for the right-hand board of the leftmost cassette. Columns D through Q contain formulas that result in pointers to all the other boards in the other cassettes. Columns S through AH use the pointers in D through Q to look up the data presented.

The first area uses a lookup table to determine which fiber (by name) is sent over each link; for example, one cell contains A9(S1) – this means that fiber A9, which is part of sector 1, is being sent. In the second area, the names of the fibers are replaced by numerical codes which indicate how the Mixer works. The numerical codes are a four-digit value where the digits all have unique meaning:

- The thousands digit indicates which Mixer Board receives the bit, from the Mixer Board page. All the numbers within a set of 20 rows (one color) have to have the same thousands digit, as they're all part of one physical LVDS cable.
- The hundreds digit is the 'sharing' information from the Shared on DFE page. This indicates which color link out to the DFEs the bit belongs to.
- The tens and ones digits indicate the sector number of the fiber, which is also an indication of which DFE should receive the fiber.

The generic organization displayed in Figure 3 hints at the fact that a given Mixer output board always sends four adjacent sector's worth of data to two DFEs.

Adjacent to the number-code group is a histogram where all the possible number codes are listed. Further to the right of the histogram are four calculated areas which show, for each of the four Mixer boards, how many bits are presented to each sector, and how they map through the Mixer. In each of the four cases, the bits are grouped. The bits in the heavy box flow straight through the Mixer board, and are what we hope happens. The other bits – shaded grey, orange and red – have to be passed between Mixer boards on the Mixer backplane. The count of these should be minimized.

The third major colored area shows the MCM pins and is presented only to allow a cross-check that all AFE boards, of either handedness, work the same way.

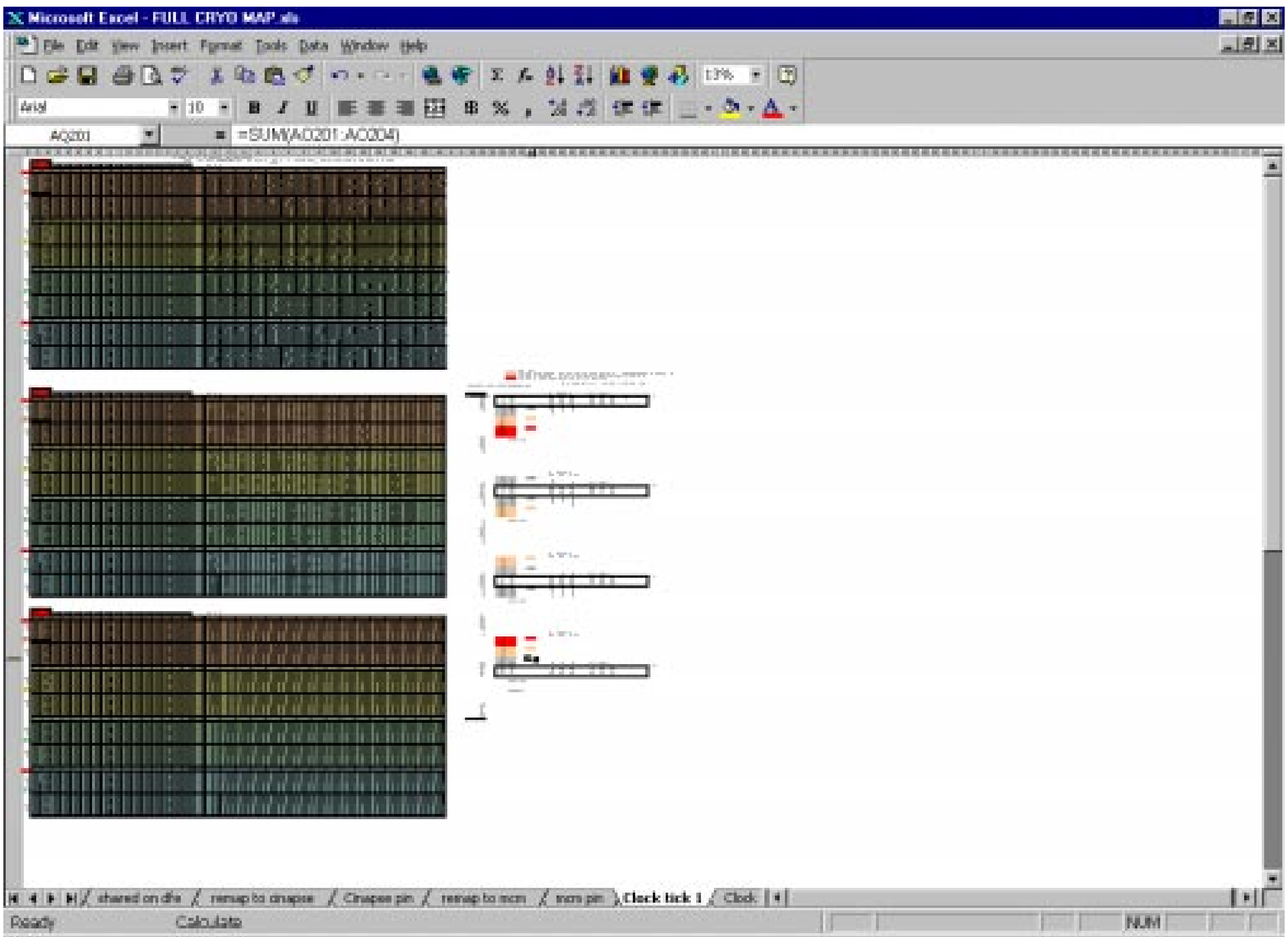

Figure 5

Implicit in the Clock Tick pages is a readout algorithm on the AFE boards where the fibers presented to a given Cin:Apse connector are scanned. The rules of this implicit algorithm are pretty simple:

- Every Cin:apse connector is assumed to drive the first 64 channels of each MCM, leaving the last 8 channels undriven.
- LVDS link #1 is connected only to MCMs #1 and #2. LVDS link #2 services MCM's #3 and #4, etc.
- Each MCM asserts 9 bits of data to its LVDS link on 6 of the 7 clock ticks, and 10 bits on the 7^{th}. MCMs 1 & 8 drive 10 bits on Clock Tick 1, MCM #2 on tick #2, MCM #3 on tick #3, etc.
- A fixed pattern is used for the readout within a given Warm End connector as shown in Figure 6. The positions marked '1' are read out in clock tick #1, '2' during tick #2, etc. The one position marked 'X' is read out in different clock ticks depending on which Warm End connector you look at. For MCM's 1 & 8, the 'X' bit comes out in clock tick #1; for MCM #2, it is read out on clock tick #2, etc. Of course, this pattern is mirror-imaged for the right-hand boards.

1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
1	2	4	6
X	3	5	7
7	7	7	7
6	6	6	6
5	5	5	5
4	4	4	4
3	3	3	3
2	2	2	2
1	1	1	1

Figure 6

Mixer Density

This page collects together the bit counts and backplane pin counts from the seven clock tick pages and summarizes the counts in a simple table. The first table is the number of bits delivered to the Mixer boards from the AFE's, and the second is the number of bits passed across the backplane.

MCM Overview

This page simply shows the number of bits sent, by MCM, per clock tick, as described in text above.

SVX Channel

This page redisplays the 'cassette view' of the first pages, but using the MCM information, tells which fiber and which SVX channel the fiber shows up on. A code such as "C1-L-A-16: fiber A3 (sector 1 rel. pos. 3)" means that Fiber A3, which is the third fiber in sector #1, comes from cassette #1 (C1), the left board (L), from MCM 'A', SVX channel 16. This information may be used to develop lookup tables for the L3 readout.